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(54) Title: PURIFICATION ELEMENTS AND PACKS

(57) Abstract

The disclosure describes a purification pack and a purification element, each including a sorbing medium. In various embodiments: the sorbing medium may comprise a copolymer or a derivative thereof, the copolymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative, and an olefin comonomer; the sorbing medium may comprise a fibrous sorbing medium, the fibers including a polymer or a derivative thereof, the polymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative; the purification pack may comprise a sorbing medium and a drainage layer adjacent to the sorbing medium; and/or the purification pack may comprise an upstream drainage layer, a sorbing medium and the filter medium are in fluid communication with each other and are interposed between the upstream and downstream drainage layers.

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PURIFICATION ELEMENTS AND PACKS

Background of Invention

Many processes are used to separate a liquid phase from another phase. Removal of minor amounts of a first liquid phase, known as a "discontinuous phase", from a second fluid phase in which it is suspended, known as the "continuous phase", covers a considerable range of situations. For example, devices have been used to separate small amounts of moisture from petroleum-based fuels, including gasoline, diesel and aviation fuels, such as kerosene; remove moisture from cleaning fluids; separate oil from coolants and parts cleaners; remove oil contamination found in natural bodies of water; separate immiscible solvent systems used in extraction processes, etc.

The presence of an unwanted discontinuous liquid phase in a desired continuous phase fluid can be problematic. For example, the presence of moisture in fuel stored in a fuel storage tank can promote corrosion of the tank. This corrosion liberates small particles of metal oxides, primarily iron oxides, from the tank walls, which can then become suspended in the continuous fuel phase and/or in the discontinuous water phase. If the fuel is to be used in a combustion engine such as a gasoline, diesel or jet engine, the particulate matter (e.g., rust particles) can damage various metal parts which are machined to high tolerances. Further, water in the contaminated fuel can cause parts of the combustion engine to corrode. In another example, the presence of water in some continuous phase fluids such as lube oils can promote the formation of acids in such fluids. The removal of these acids is costly and time consuming.

Thus, it would be desirable to remove a discontinuous phase liquid and/or solids from a continuous phase fluid stream, and to know when the amount of the discontinuous phase liquid in a continuous phase fluid becomes unacceptable.

Summery of Invention

In accordance with one aspect of the invention, a purification pack or a purification element includes a sorbing medium.

In accordance with another aspect of the invention, a purification element comprises a sorbing medium including a copolymer or a derivative thereof, the

copolymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative, and an olefin comonomer.

In accordance with another aspect of the invention, a purification element comprises a fibrous sorbing medium, the fibers of the sorbing medium comprising a polymer or ~~a~~ derivative thereof, the polymer carboxylic acid or carboxylic acid derivative.

In accordance with another aspect of the invention, a purification pack comprises a sorbing medium and a drainage layer adjacent ~~to the~~ sorbing medium.

In accordance with another aspect of the invention, a purification pack comprises an upstream drainage layer, a sorbing medium, a filter medium, and a downstream drainage layer, wherein the sorbing medium and the filter medium are in fluid communication with each other and are interposed between the upstream and downstream drainage.

Favorably, purification elements and packs embodying the invention can have better sorbing and purifying properties than many conventional elements and packs. For example, purification elements and packs including the sorbing media according to the invention can exhibit sorbing capacities greater than conventional purification elements and packs, can exhibit faster sorbing rates than conventional purification elements and packs' and/or can exhibit more even sorbing characteristics than conventional purification elements and packs.

Brief Description of the Drawings

Figure 1 is a partial cross-sectional view of a purification device.

Figure 2 is a transverse cross-sectional view of a portion of a purification device.

Figure 3 is a partial cross-sectional view of a purification apparatus.

Figure 4 is a diagram of a purification system.

Detailed Description

While many embodiments of the invention will be described with respect to the removal of water from fuel, the invention is not limited to the removal of water from fuel. For example, a wide variety of other discontinuous phase liquids, such as brine and electrolyte solutions may be removed from any continuous phase fluid such as a liquid, a gas, or a mixture thereof.

Figure 1 illustrates one of many examples of a shaped purification device 10 according to an embodiment of the invention. The illustrated purification device 10 includes a hollow, cylindrical, tubular core 11, which is surrounded by a pleated, purification element 20. A wrap member 30 is helically wrapped around the purification element 20 so that gaps 32 are provided between adjacent turns of the wrap member 30. An open end cap 13 and a closed end cap 12 may be positioned at opposite ends of the purification device 10. The two end caps 12, 13, can be made of metal or plastic, and can cooperatively function to secure the core 11, purification element 20 and the wrap member 30 together. To impart further structural stability to the purification device 10, a bonding structure 33 such as a fusion bond may be used to bond the purification element 20 to the wrap member 30.

Illustratively, a contaminated fuel stream containing water as a discontinuous phase liquid and fuel as a continuous phase fluid can be purified with the purification device 10 shown in Figure 1. The contaminated fuel stream can be directed in a radially inward direction through the wrap member 30 or in the gaps 32 defined by the wrap member 30. As the contaminated fuel stream passes radially inward through the purification element 20, water and/or solid contaminants may be removed by the purification element 20 forming a purified fuel stream. For example, the purification element 20 can include a sorbing medium and a filter medium adjacent to, or spaced from, one another. Alternatively, the purification element can include a sorbing medium and no filter medium. The sorbing medium may primarily remove water and solid contaminants from the fuel stream while the filter medium primarily removes solid contaminants from the fuel stream. Once formed, the purified fuel stream can pass into the core 11, inside the core in an axial direction, and then out through the open end cap 13 of the purification device 10. The purified fuel stream can then pass downstream, e.g., to an engine or to storage. While the contaminated fuel stream has been described as passing through the purification element 20 in a radially inward direction, the contaminated fuel stream may alternatively be purified by passing through the purification element 20 in a radially outward direction.

Figure 2 shows a transverse sectional view of a purification device 10. The purification device 10 has a core 11 at an inner part of the purification device 10 and a wrap member 30 at an outer part. A pleated, purification element 20 is disposed between the core 11 and the wrap member 30. The purification element 20 has more than one layer and comprises, in a direction from the core 11 to the wrap member 30:

a downstream drainage layer 25; a filter medium 24; a sorbing medium 23; a cushioning layer 22; and an upstream drainage layer 21. These and other components which can be used in the purification element will be described in more detail below.

The purification element according to embodiments of the invention may include a sorbing medium. Optionally, the purification element may also include at least one of a filter medium, drainage layer, cushioning layer, coalescing medium, and liquophobic medium in any suitable combination, and in any suitable relative positions. Any suitable combination of these components may be combined or used alone to form a purification pack.

Regardless of the particular components chosen for the purification element, at least part of the purification element is preferably pleated to increase the surface area, and therefore the purification area, of the purification element for a predetermined envelope (e.g., a housing). The pleats can be, e.g., radially disposed as described in U.S. Patent 5,252,207, which is herein incorporated by reference in its entirety. Although all of the layers of the purification element illustrated in Figure 2 are pleated, some layers of the purification element may be pleated and some may not be. For example, a purification element can include a pleated structure including a filter medium and one or more drainage layers, with a non-pleated sorbing medium disposed adjacent to the upstream pleat tips of the pleated structure and/or a non-pleated sorbing medium disposed adjacent to the downstream pleat tips of the pleated structure (e.g., cylindrically disposed around a core or adjacent to a cage or a wrap).

If the purification element is pleated, the pleated structure of the purification element can be produced in any suitable manner. Preferably, the layers forming the purification element are co-corrugated. For example, a layer of filter medium and a layer of sorbing medium can be placed between two drainage media to form a composite. The composite can then be co-corrugated to form a pleated structure.

Preferably, the sorbing medium comprises an expandable material such as a superabsorbent. Superabsorbents are preferred, because they can absorb relatively large quantities of liquid. For example, a typical superabsorbent can absorb between about 25 to about 1000 times its weight in liquid. Advantageously, a purification device having a superabsorbent sorbing medium can be changed with less frequency, because relatively large amounts of liquid can be absorbed by the purification device before becoming loaded or spent.

A purification device having an expandable medium such as a superabsorbent sorbing medium can provide for other advantages. For example, a purification device can be designed so that the flow of fluid passing through the purification device significantly slows or substantially stops if, e.g., the purification device is spent or if the level of discontinuous phase liquid passing through the purification device is unacceptable. Typically, as a superabsorbent in a sorbing medium accumulates liquid, the superabsorbent swells and expands. The swelling and expanding superabsorbent causes any pores in the sorbing medium to become smaller and smaller. Eventually, the pores in the sorbing medium may substantially close so that the sorbing medium develops into a substantially fluid impermeable structure, which prevents appreciable amounts of fluid from passing through the sorbing medium and corresponding purification device. The purification device can thus automatically slow down or substantially shut off the flow of fluid passing through the purification device, preventing the unacceptable levels of discontinuous phase liquid from passing downstream. The closing of the pores of the sorbing medium can create a relatively rapid increase in the pressure drop across the corresponding purification device and/or decreased flowrate downstream of the purification device. The increased pressure drop and/or decreased flowrate can be sensed by a monitoring device, which can inform a system or operator that corrective action needs to be taken. For example, an increase in the pressure drop across the purification device or a reduced flowrate downstream of the purification device may signal that the purification device is spent and needs to be changed.

The sorbing medium can include, or be derived from, a polymer or copolymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative. Preferably, the sorbing medium can include a copolymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative, and an olefin comonomer (e.g., an olefin/alkylene carboxylate copolymer). Such copolymers can be particularly suitable for forming superabsorbent fibers having increased sorbing capacities and increased sorbing rates. In the copolymer, the monomers and comonomers may be present in any suitable proportion. Preferably, the polymers and/or copolymers of the sorbing medium are crosslinked.

Suitable unsaturated monomers used to form the polymer or copolymer can include those which have at least one pendant carboxylic acid group or a derivative

thereof. Derivatives of carboxylic acids include carboxylic acid salt groups, carboxylic acid amid groups, carboxylic acid imide groups, carboxylic acid anhydride groups and carboxylic acid ester groups. Suitable unsaturated monomers can include maleic acid, crotonic acid, fumaric acid, mesaconic acid, and salts (e.g., sodium salts) thereof. Other unsaturated monomers may include maleic anhydride, fumaric anhydride, itaconic anhydride, citraconic anhydride, mesaconic anhydride, methyl itaconic anhydride, ethyl maleic anhydride, and the like.

Any suitable comonomer can be used to form the copolymer. Preferably, the comonomer includes an olefin comonomer. Exemplary comonomers can include alpha-olefins, vinyl monomers, and vinylidene monomers. More specific examples of comonomers can include ethylene, propylene, isobutylene, 1-butylene, alkyl methacrylates, vinyl acetate, methyl vinyl ether, isobutyl vinyl ether, and styrenic compounds.

Specific examples of polymers which may be used to form the sorbing medium include olefin/maleic anhydride copolymers, olefin/citraconic anhydride copolymers, olefin/acrylic acid copolymers, vinyl compound/maleic anhydride copolymers, vinyl compound/citraconic anhydride copolymers, vinyl compound/acrylic acid copolymers, alkylacrylate/maleic anhydride copolymers, alkyl acrylate/maleic anhydride copolymers, alkyl vinyl ether/citraconic anhydride copolymers, alkyl vinyl ether/citraconic anhydride copolymers, alkyl vinyl ether/citraconic anhydride copolymers, vinyl acetate/maleic anhydride copolymers, olefin/maleic anhydride/olefin terpolymers, polyacrylic acid, polymethacrylic acid, derivatives thereof, and combinations, blends, and the like.

If desired, pendant carboxylic acid or carboxylic acid derivatives on the polymer or copolymers can be neutralized with any suitable substance including strong organic or inorganic bases such as NaOH, KOH, lithium hydroxide, ammonium hydroxide, ammonia, and ammonia-in-water to produce a polymer or copolymer having a desired functionality and desired sorbing properties. For example, a polymer having pendant carboxylic acid groups can be neutralized with sodium or lithium hydroxide to produce a polymer having pendant carboxylate sodium or lithium salt groups and pendant carboxylic acid groups.

Preferably, the polymer or copolymer of the sorbing medium includes carboxylate salt groups such as carboxylate metal salt groups. More preferably, the metal of the carboxylate metal salt groups can include an alkali metal such as sodium

or potassium. For example, the sorbing medium may include a maleic anhydride/isobutylene copolymer derivative having pendant carboxylate metal (e.g., Na) salt groups and pendant carboxylic acid groups, or a poly(acrylic acid) having pendant carboxylate metal (e.g., Na) salt groups.

The sorbing medium may include other components such as inorganic salts, neutralizing agents, crosslinking agents, and other additives to impart specifically desired properties to the sorbing medium (e.g., greater water retention or shelf life). These components may be used with the above described polymers and copolymers.

The form of the sorbing medium is not limited. The sorbing medium can include any suitable combination of sorbing and/or non-sorbing components in any suitable form including particles, fibers, sheets, granules, etc. For example, a sorbing medium may include one ~~or~~ more pleated or unpleated nonwoven superabsorbent fabric (e.g., nonwoven or woven) layers. In yet another embodiment, the sorbing medium may include one or more perforated, expanded, and/or slitted sheets (e.g., a superabsorbent sheet). In another embodiment, the sorbing medium can be in the form of a bed. For example, the sorbing medium can include an aggregate of superabsorbent particles or fibers sandwiched between two porous sheets. This sandwiched structure can be pleated or unpleated, and can be positioned adjacent to any suitable structure such as a core or a pleated or unpleated filter medium. In still another embodiment, the sorbing medium may include a superabsorbent open cell foam. If the sorbing medium is in the form of a sheet, the thickness of the sheet can be of any suitable thickness. For example, the thickness of the sorbing medium can be between about 5/1000 to about 100/1000 inches thick.

In a preferred embodiment, the sorbing medium may comprise one or more non-sorbing structures (e.g., a non-woven polypropylene sheet) impregnated with a sorbent (e.g., superabsorbent polymer fibers or particles) or coated with a sorbent. For example, the sorbing medium can include a blend of sorbing or non-sorbing fibers in any suitable proportion. The sorbing medium can include between about 20-100 wt. or volume % sorbing material (e.g., fibers) in combination with a non-sorbing material (e.g., polyolefin fibers). Preferably, the sorbing medium includes 40-60 wt. or volume % sorbing material (e.g., fibers such as superabsorbent fibers) in combination with a non-sorbing material (e.g., polyolefin fibers). Suitable sorbing media can be obtained from Concert Fabrication Co., of Thurso, Quebec.

In one preferred embodiment, the sorbing medium includes a fibrous medium with sorbing fibers. Although sorbing particles can be used in the sorbing medium, sorbing fibers are preferred. Sorbing particles are typically disposed on or in a supporting structure such as a sheet and may have a tendency to move from where they are placed. This may be particularly true if the sorbing particles are to be subjected to high pressure from a high pressure fluid stream. To help inhibit the unwanted movement of sorbent particles in the sorbing medium, sorbing particles are typically bonded, fused, imbedded or laminated to another structure of the sorbing medium to keep the sorbing particles in place. This process can be time consuming and expensive. In contrast, sorbing fibers can exhibit relatively consistent sorbing properties, and can be relatively easily formed into a stable sorbing medium. A fibrous sorbing medium does not necessarily require bonding, fusing, imbedding and/or lamination to maintain the structural integrity of the sorbing medium.

Another advantage of using sorbing fibers in a sorbing medium is that sorbing fibers can remove both discontinuous phase liquids and solid contaminants from a continuous phase fluid stream. Accordingly, a purification device having a purification element comprising sorbing fibers can be used as both a discontinuous phase liquid removing device as well as a solid contaminant removing device. Consequently, the layers in a purification device may be reduced providing for increased surface area within a given envelope and reduced production costs.

For example, a contaminated fuel stream having water and solid contaminants may be purified with a purification device having a superabsorbent ~~woven or~~ nonwoven fabric as a sorbing ~~medium,~~ but no filter medium. As the contaminated fuel stream passes through the sorbing medium, the superabsorbent fibers can absorb the water from the fuel. While the superabsorbent fibers absorb water, the fibrous structure of the sorbing medium can also trap solid contaminants in the fuel stream, thus removing them from the fuel stream. The solid contaminants can be sieved or trapped by the tortuous flow paths created by the sorbing medium's woven or nonwoven structure.

If the sorbing medium comprises fibers, the fibers can include staple, chopped, bulk, and fluffed fibers, filaments, strands, yarns, and webs. Preferably, the fibers have a cut length of from about 6-52 mm, or from about 6-50 mm. Alternatively or additionally, the fibers can have an average denier between about 5 and 15, and preferably an average denier of about 10. The sorbing fibrous medium may include a

structure such as a scrim, a woven fabric, a nonwoven fabric, a mesh, or a batt. In a preferred embodiment, the sorbing medium may include type of material similar to Fiberdri® sorbent or Fibersorb® sorbent both of which are commercially available from the Camelot Technologies, Inc., of Calgary Canada. Fiberdri® sorbent has been described as including an olefin/alkyl carboxylate copolymer and inorganic salts. Advantageously, a purification element having Fiberdri® sorbent, Fibersorb® sorbent, or the previously mentioned materials, can exhibit sorbing capacities which are at least about twice as great as conventional purification elements. Another suitable, but less preferred sorbent is Oasis® sorbent, which is commercially available from Technical Absorbents Ltd.

The purification element may also include a filter medium in addition to the sorbing medium. The filter medium may be selected in accordance with several factors, including the nature of the fluid being filtered, the nature and size of the contaminants in the fluid, and the acceptable pressure drop across the purification element. The filter medium may include any suitable structure and can be primarily intended ~~to remove solids~~ from a fluid stream. For example, the filter medium may comprise a porous metal or ceramic medium. More preferably, the filter medium may be fashioned as a membrane, woven or nonwoven fibrous sheet and/or a fibrous mass and may be fabricated from a natural or synthetic polymer or glass. Thus, the filter medium may comprise a nonwoven sheet principally including cellulose fibers or essentially consisting of glass fibers with a resin binder. In a preferred embodiment, the filter medium comprises a suitable grade of a glass fiber acrylic bonded medium with an integral substrate providing additional strength. Preferred media, including a family of fibrous filter media having various binder resins, are available from Pall Corporation under the trade names Ultipor® and Pallflex®. Furthermore, the filter medium may have any desired pore structure, including a graded pore structure, and any desired removal rating. The filter medium may also be liquophobic or rendered liquophobic by any suitable treatment.

If the purification element includes a filter medium, the filter medium may be positioned at any suitable position relative to the sorbing medium. In one embodiment, the filter medium can be positioned upstream of the sorbing medium. By doing so, a fluid stream may be purified more efficiently, because the filter medium can remove particulate contaminants which, if present on the sorbing medium, may obstruct the sorbing surfaces of the downstream sorbing medium. For

example, a fuel stream having water as a discontinuous phase and solid contaminants can be passed through a purification element comprising an upstream filter medium and a downstream sorbing medium. The solid contaminants can be removed from the fuel stream by the filter medium, thus forming a fluid stream consisting essentially of fuel and water. The substantially solid-free, water-containing fuel stream can then pass through the sorbing medium, which does not have its surfaces blocked by solid particles. In the sorbing medium, water is removed from the fuel stream to produce a fuel stream substantially free of both solid contaminants and water. In another embodiment, the filter medium can be positioned downstream of the sorbing medium. By doing so, the sorbing medium may serve as a prefilter for the filter medium. Positioning a prefilter upstream of a downstream filter medium can increase the useful life of the filter medium. For example, an upstream prefilter (e.g., a sorbing medium) can capture large particles in a fluid stream which may otherwise collect on the upstream surface of, and prematurely clog a downstream filter medium.

If desired, the purification element may include a coalescing medium. A coalescing medium can coalesce discontinuous phase liquid particles in a continuous phase fluid to form large, coalesced droplets of discontinuous phase liquid. These large, coalesced droplets are larger than the uncoalesced discontinuous phase liquid particles and may be easier to separate from a continuous phase fluid stream than the small, uncoalesced discontinuous phase liquid particles. For example, a contaminated fluid stream with uncoalesced discontinuous phase liquid particles in a continuous phase fluid can pass through a coalescing medium and then to a sorbing medium. In the coalescing medium, the discontinuous phase liquid particles can coalesce into larger droplets of liquid. As the fluid stream passes to the sorbing medium, the large size of the coalesced droplets increases the likelihood that the discontinuous phase liquid can be intercepted and sorbed by the downstream sorbing medium. Thus, while the coalescing medium may be positioned downstream of the sorbing medium, the coalescing medium is preferably upstream. Further, while the coalescing medium may be arranged to coalesce a different discontinuous phase than that sorbed by the sorbing medium, the coalescing medium is preferably arranged to coalesce the same discontinuous phase that the sorbing medium sorbs.

The purification element may also include drainage layers. If the purification element includes drainage layers, the drainage layers are preferably very open, allowing fluid to flow laterally and to uniformly distribute the fluid across the surface

of an adjacent layer or medium. Thus, the drainage layers typically have a very low edgewise flow resistance. The drainage layers can also prevent pleated surfaces of a layer or medium, such as a filter and/or sorbing medium from coming into contact with one another and thereby reducing the effective surface area of the layer or medium. The drainage layers can do so by providing a positive spacing (fanning) between adjacent pleats of a layer or medium and/or drainage passages between adjacent pleats.

Any suitable woven or nonwoven material having good porosity can be used for an upstream drainage layer and/or downstream drainage layer. Furthermore, either layer may be fabricated from one or more of natural fibers, polymeric materials, and/or glass. In a preferred embodiment, the drainage layers comprise an extruded polymeric mesh. The mesh can be fabricated from any polymeric material, including polyester, polypropylene, or polyamide such as nylon. The mesh is preferably as smooth as possible to reduce abrasion between it and the underlying layers. Extruded polymeric mesh is generally preferable to other support and drainage materials, including woven and nonwoven fibrous webs and polymeric netting, because it is so smooth and because it typically does not shrink during fabrication and corrugation of the purification element.

Meshes and screens (also called netting) come in various forms. For high temperature applications, a metallic mesh or screen may be employed, while for lower temperature applications, a polymeric mesh may be particularly suitable. Polymeric meshes come in various forms, such as woven, expanded, or extruded meshes. Either type may be employed, but extruded meshes are generally preferable because they are smoother and therefore produce less abrasion of adjoining layers of the composite. The meshes or screens, including an extruded mesh may have a first set of parallel strands in a first plane and a second set of parallel strands in a second plane intersecting the first set of strands at an angle. The first and second set of parallel strands can also lie adjacent to each other in two parallel and adjacent planes. In this regard, the mesh can be a bi-planar or three-dimensional mesh. Specific examples of suitable extruded polymeric meshes are those available from Nalle Plastics (Austin, Texas) under the trade names Naltex, Zicot, and Ultraflo. The mesh may also have any suitable number of strands per inch. For example, the mesh may have at least about 10 strands per inch if the mesh is downstream of the sorbing medium. A mesh upstream of the sorbing medium can have at least about 5 strands per inch.

In a preferred embodiment, the purification element can have a drainage layer upstream and/or downstream and preferably adjacent to a sorbing medium. By providing an upstream drainage layer adjacent to a sorbing medium, a fluid stream can be more evenly distributed at the sorbing medium surface. Advantageously, a discontinuous phase liquid in a continuous phase fluid can be distributed and sorbed evenly across the entire surface of the sorbing medium. Evenly distributing the fluid provides more uniform sorption of the discontinuous phase liquid by the sorbing medium and, in turn, maximizes the sorbing capacity of the sorbing medium. For example, if the sorbing medium is expandable, the sorbing medium can expand evenly when sorbing a discontinuous phase liquid. Purification devices having an unevenly expanding sorbing medium may have to be changed more frequently, because the more rapidly expanding portions of the sorbing medium may prematurely cut off flow to the other portions of the purification device (e.g., other regions of the sorbing medium or portions of a filter medium). Consequently, the purification device may have to be changed before the sorbing medium has reached its maximum sorbing capacity.

Furthermore, by providing a drainage layer adjacent to a sorbing medium, an expandable sorbing medium (e.g., superabsorbent) can have even more room to expand, thus increasing the equilibrium sorption capacity of the sorption medium. For example, in embodiments of the invention, a purification element may have an upstream drainage mesh, a sorbing medium, and a downstream drainage mesh. Both the upstream and downstream meshes can be relatively open structures capable of providing an even flow distribution at the sorbing medium surface and capable of providing an expandable area for the sorbing medium. As the sorbing medium sorbs a discontinuous phase liquid, the sorbing medium can expand and permeate into the upstream and downstream meshes. The increased expansion area provided by meshes adjacent the sorbing medium permits the sorbing medium to sorb more liquid, thus increasing the sorption capacity of the sorbing medium.

The purification element may also include one or more cushioning layers. A principal purpose of the cushioning layer is to prevent abrasion between the drainage layer, and a layer or medium such as a filter medium and/or sorbing medium. For example, the above described drainage layer typically has good drainage properties because it is fashioned from relatively large fibers or filaments. Consequently, it generally has a rougher surface than, e.g., a filter or sorbing medium. When such a

material is laminated directly to a filter and/or sorbing medium, for example, significant abrasion of the filter and/or sorbing medium can result when the purification element undergoes flexing, for example, due to pressure cycles, and the drainage layer repeatedly rubs against the layers of the purification element. However, when a cushioning layer, which is smoother than a drainage layer, is interposed between the drainage layer, and a filter medium and/or sorbing medium, the abrasion of the filter and/or sorbing medium can be greatly reduced, resulting in an increase in the useful life of the purification element and a corresponding purification device.

The cushioning layer is preferably formed of a thin, very porous material. For example, the cushioning layer preferably has a thickness of less than 100 microns. It is also preferably formed from a material which can be characterized as smooth or as smooth and tough. For example, it may be a non-abrasive, nonwoven material with a high tensile strength. A preferred material for the cushioning layer is a wet-laid polyester nonwoven material sold by Hirose Corporation under the trade designation 05TH08. Other preferred materials include a nylon nonwoven material available from Fiberweb North America Inc. under the trade designation Cerex and a nonwoven polyester material available from Reemay Corporation under the trade designation Reemay, such as Reemay 2006 or Reemay 2250. Of these materials, the materials from Hirose and Reemay are most preferred.

The purification element may also comprise a liquophobic layer adjacent to the sorbing medium. The liquophobic layer can be phobic with respect to the discontinuous phase liquid in a continuous phase fluid stream, but is preferably philic with respect to the continuous phase. Exemplary liquophobic layers include hydrophobic or oleophobic layers. The liquophobic layer can be in any suitable form and can include any suitable material. For example, the liquophobic layer can include structures such as meshes or fabrics including those used for the previously described drainage layers or filter media. Such structures can be used in addition to the drainage layers or filter media, and can be inherently liquophobic or rendered liquophobic by any suitable treatment.

The liquophobic layer can be in any suitable position relative to the other components of the purification element. Preferably, at least one liquophobic layer is preferably positioned downstream and optionally upstream of, and adjacent to the

sorbing. If desired, the liquophobic layers can contact the sorbing medium. More preferably, the sorbing medium is interposed between two or more liquophobic layers.

By using a liquophobic layer in combination with, e.g., downstream from, the sorbing medium, the residence time of the discontinuous phase liquid at the sorbing medium can be increased, thus increasing the likelihood that sorbing medium can sorb the discontinuous phase liquid. For example, a contaminated fluid stream having water as a discontinuous phase and fuel as a continuous phase can be passed through a purification element having an upstream sorbing medium and a downstream hydrophobic layer adjacent to the sorbing medium. As the fuel/water stream passes through the sorbing medium, the sorbing medium sorbs most of the water from the fuel stream. However, some water may inadvertently pass downstream of the sorbing medium. The downstream hydrophobic layer can deflect and repel this water in an upstream direction, while permitting the fuel to pass through it and downstream. The deflected or repelled water can be re-directed towards the sorbing medium, thus permitting the sorbing medium to sorb the deflected or repelled water.

The liquophobic layer may also be positioned upstream of the sorbing medium. By doing so, the liquophobic layer may, e.g., act as a discontinuous phase separator, while the downstream sorbing medium serves to sorb any discontinuous phase liquid that happens to pass downstream of the liquophobic medium. For example, a fluid stream having gas as a continuous phase, and water aerosols as a discontinuous phase can be directed to a purification element having an upstream porous hydrophobic medium and a downstream sorbing medium. As the fluid stream contacts the hydrophobic medium, most of the water aerosols will not pass through the hydrophobic medium, but will simply contact and collect on the upstream surface of the hydrophobic medium and then separate from the gas (e.g., by gravity). Any water aerosols that happen to pass through the hydrophobic medium can be sorbed by the downstream sorbing medium, thus creating a purified gas stream substantially free of water aerosols.

The purification element can be incorporated into a purification device. The purification device may be in any suitable form. For example, the purification device may be shaped as a cylinder or parallelepiped having a square or rectangular cross section. In such an embodiment, the purification device can include a frame with a purification element attached to the inside of the frame. If cylindrically shaped, the purification device can include a pleated or non-pleated purification element

cylindrically and, permanently or removably disposed around a hollow perforated cylindrical core such as a hollow, porous tube. The core can be made of any suitable material and may structurally stabilize the purification element. A wrap member or a cage may be disposed around the cylindrically shaped purification element to further support the purification element.

Regardless of the particular shape of the purification device, the purification device is preferably removable and/or replaceable once the purification device outlives its useful life. For example, the purification device can become spent after purifying a fluid stream for an extended period of time, thus requiring replacement.

Alternatively or additionally, any particular component or components of the purification device may be demountable or separable from the other components of the purification device in order to facilitate easy replacement of the demountable or separable components. Replacement of a demountable or separable component may occur while the purification device is separated from, or forms part of a larger purification apparatus or system. This may be preferable, because purification device components such as the purification element, sorbing medium, filter medium, and other component(s) may foul or become spent more quickly than other components, and may thus require replacement more often than other components. In one embodiment, the purification element may be removable or demountable with respect to other components of a purification device, such as the cage, core and/or end caps of the purification device. For example, with respect to the purification device 10 shown in Figure 1, either or both of the end caps 12, 13 can be temporarily or permanently removable. The purification element 20 can be axially moveable with respect to the purification device 10 to facilitate replacement of the purification element 20, on for example, a reusable core or cage. If the purification element 20 becomes fouled or damaged, the purification element 20 may be removed, and replaced with a new purification element without replacing the entire purification device 10. In another embodiment, the sorbing and/or filter medium (alone or as part of a sorbing element or filter element) may be detachably mounted and/or axially moveable with respect to, e.g., each other, the purification element 20 or purification device 10. Selectively replacing fouled, spent or damaged components of a purification device can be more efficient and economical than replacing the entire purification device.

One or more purification devices 10 may be incorporated into a purification apparatus. A purification apparatus 40 is shown in Figure 3. Figure 3 shows a

purification apparatus 40 having a housing 50 with a fluid inlet 43 and a fluid outlet 41. A plurality of purification devices 10 having a cylindrical shape are disposed within the housing 43. Each of the purification devices 10 can include open end caps 13 and closed end caps 12 at opposing ends. The plurality of purification devices 10 can be secured within the housing 50 with the help of a stabilizing structure 46, such as a support plate or a tubesheet.

In an illustrative method, a water-contaminated fuel stream 44 can be introduced to the plurality of purification devices 10 via the fluid inlet 43. The contaminated fluid stream 44 can then enter the housing 50 and pass through one of the cylindrically shaped purification devices 10 in a radially inward direction. As the contaminated fluid stream 44 passes through the plurality of purification devices 10, water and other contaminants (e.g., solid particles) can be removed by the purification elements (not shown) of the purification devices 10. After passing through the purification elements of the purification devices 10, individual purified fuel streams 42 are formed inside the purification devices 10. The purified fuel streams 42 can pass inside the purification devices 10 in an axial direction towards and through the open end caps 13. After passing through the open end caps 13, the individual purified fuel streams 42 in the purification devices 10 can merge and exit the purification apparatus 40 through the fluid outlet 41. Although this illustration describes a water-contaminated fluid being directed from outside the purification devices 10 to inside the purification devices 10, the water-contaminated fluid may flow in the opposite direction. For example, a water-contaminated fluid may be purified by directing the water-contaminated fluid from inside the purification devices 10 to outside the purification devices 10.

Embodiments of the invention can also relate to a purification fuse. A purification fuse can be used to indicate when the level of discontinuous phase liquid in a continuous phase fluid stream has become unacceptable. Once an operator or system observes this indication, the flow of fluid passing through the purification fuse can be terminated or adjusted automatically or manually. Termination or adjustment of the fluid flow may be desirable if the amount of discontinuous phase liquid passing through the purification fuse has become unacceptable. For example, a contaminated fluid passing through a purification fuse may include an amount of discontinuous phase liquid (e.g., a slug of liquid) which is greater than can be normally processed by a downstream purification apparatus. In this instance, it may be desirable to terminate

the flow of fluid passing through the purification fuse and determine why the amount of discontinuous phase liquid in the contaminated fluid stream is greater than would normally be expected. Otherwise, the downstream purification apparatus may premature foul, rendering the apparatus ineffective to purify the fluid stream. Over time, it may be desirable to change or replace the purification fuse. For example, the purification fuse can gradually sorb small, but acceptable amounts or concentrations of discontinuous phase liquid over time. At some point, the sorbing medium of the purification fuse may reach its sorbing capacity, and may thus have to be changed or replaced.

The purification fuse can include a sorbing medium and can have any suitable configuration. For example, the purification fuse can be configured in the same or different manner as any of the purification device embodiments. In one embodiment, the sorbing medium can be pleated or unpleated in the purification fuse. For example, the sorbing medium can be cylindrically shaped and disposed adjacent to a core, or a wrap or a cage. If desired, the cylindrically shaped sorbing medium can be adapted to shut down quickly if the amount of discontinuous liquid in a continuous phase fluid becomes unacceptable. In addition, a wrap member is preferably used as a component of the purification fuse. By incorporating wrap member in a purification fuse, the purification fuse can be designed to shut down quickly if the wrap member keeps components of the purification element wrapped tightly together. Further, the purification fuse can sorb a discontinuous phase liquid, and can be used alone or with other devices to terminate or adjust the flow of a fluid stream.

In one embodiment, the purification fuse can be designed so that the flow of the fluid stream passing through the purification fuse automatically slows or substantially stops if the level of discontinuous phase liquid passing through the purification fuse is unacceptable. In this embodiment, the purification fuse can include an expandable sorbing medium, including a superabsorbent sorbing medium such as those previously described. As the superabsorbent in a sorbing medium accumulates liquid, the superabsorbent swells and expands. The swelling and expanding superabsorbent causes any pores in the sorbing medium to become smaller and smaller. Eventually, the pores in the sorbing medium may substantially close so that the sorbing medium develops into a substantially fluid impermeable structure, which prevents any appreciable amount of fluid from passing through the sorbing medium and corresponding purification fuse. The purification fuse may thus

automatically slow down or significantly shut down the flow of fluid passing through the purification fuse, thus preventing unacceptable amounts of discontinuous phase liquid from passing downstream.

If desired, a monitoring device can be arranged in operative communication with the purification fuse and can indicate if the amount of discontinuous phase liquid in the continuous phase fluid stream has become unacceptable. The monitoring device may respond to a chemical, electrical or physical stimulus caused by the sorption of liquid by the sorbing medium in the purification fuse. For example, a pressure gauge and/or flowmeter may operatively communicate with the purification fuse. If a fluid stream includes an uncharacteristically large amount of discontinuous phase liquid, the sorbing medium in the fuse may sorb the discontinuous phase liquid, swell, and close any pores in the sorbing medium. The closing pores of the sorbing medium and the consequent inability of the fluid to flow through the sorbing medium can create a high pressure drop across the purification fuse and/or a reduced flowrate downstream of the fuse. The pressure gauge can sense the high pressure drop across the purification fuse and/or the flowmeter can sense the reduced flowrate downstream of the fuse. Each of these devices may subsequently indicate when the level of discontinuous phase liquid in a passing continuous phase fluid has become unacceptable. In another example, a monitoring device may include an electrical device such as a capacitance meter, which may be operatively connected to a purification fuse comprising a sorbing medium. As the sorbing medium sorbs more and more discontinuous phase liquid, the capacitance of the purification fuse may increase. The capacitance meter can sense this capacitance increase and may consequently indicate when the amount of discontinuous phase liquid in the fluid passing through the purification fuse has risen to an unacceptable level. Regardless of the particular type of monitoring device employed, corrective action can then be taken, e.g., by an operator or control system, in response to an indication provided by the monitoring device to prevent unacceptable levels of discontinuous phase liquid from passing downstream.

One or more purification devices or fuses may also be placed parallel with, upstream or downstream of, or within a purification apparatus. One or more purification fuses may be positioned in this manner to monitor the level of discontinuous phase liquid in either an incoming contaminated fluid stream or an outgoing purified continuous phase fluid stream. For example, Figure 4 shows a

schematic diagram of a fluid purification system including a purification apparatus 40, and upstream and downstream purification fuses 50(a), 50(b). Monitoring devices 52(a), 52(b) may be in operative communication with the purification fuses 50(a), 50(b).

The purification apparatus 40 may include any apparatus suitable for purifying a fluid. More specifically, the purification apparatus 40 can include an apparatus capable of removing solid and or liquid contaminants from a contaminated fluid stream. For example, the purification apparatus 40 may include one or more of a filtering apparatus, a coalescer apparatus, a coalescer/separator apparatus, a spinning disk purifying apparatus, a filtering/sorbing apparatus, etc. An example of a spinning disk purifier can be found in U.S. Patent 4,604,109, which is incorporated by reference in its entirety. Examples of suitable coalescing and/or separator apparatuses can be found in U.S. Patents 5,480,547 and 5,443,724, which are incorporated by reference in their entirety.

Advantageously, a system such as the one shown in Figure 4 can monitor the level of discontinuous phase liquid in a contaminated fluid stream and a purified fluid stream. In an illustrative example, a water-contaminated fluid stream 44 can pass through the upstream fuse 50(a). If the amount of water in the water-contaminated fluid stream 44 becomes unacceptable, the upstream fuse 50(a) can, e.g., form a physical barrier stopping the flow of the contaminated stream 44. Alternatively, the upstream fuse 50(a) can communicate with the monitoring device 52(a), which can inform an operator or a control system that the level of water in the incoming contaminated fluid stream 44 has become unacceptable so that appropriate action can be taken (e.g., shutting down the system). In either event, the presence of the upstream fuse 50(a), e.g., can help prevent unacceptable levels of water in an incoming contaminated fluid stream 44 from prematurely fouling any purification devices present in the purification apparatus 40, by automatically terminating the flow of fluid to the purification apparatus 40 and/or directly or indirectly indicating when the level of water in the contaminated fluid stream 44 is unacceptable.

After passing through the upstream fuse 50(a), the water-contaminated fluid stream passes through the purification apparatus 40 to form a purified fluid stream. After passing through the purification apparatus 40, the purified fluid stream 42 passes through the downstream fuse 50(b). The downstream fuse 50(b) can help prevent unacceptable levels of water in the purified fluid stream 42 from passing

downstream. For example, in a manner similar to the above described upstream fuse 50(b), the downstream fuse 50(b) can significantly slow down or substantially shut off the flow of purified fluid by forming a physical barrier and/or providing a stimulus to the monitoring device 52(b) which may inform an operator or control system that the level of water in the purified fluid stream 42 is unacceptable so that appropriate action can be taken (e.g., shutting down the system). The water level in the purified fluid stream 42 can become unacceptable due to a variety of circumstances. For example, a purification device (not shown) in the purification apparatus 40 may be defective thus increasing the amount of water passing downstream of the purification apparatus 40.

Although purification fuses are discussed with reference to Figure 4 for illustrative purposes, purification devices can be placed upstream and/or downstream of any suitable purification apparatus in a manner similar to the described purification fuses. This might be done to assist a purification apparatus in purifying a fluid stream.

Also, although Figure 4 illustrates contaminated and purified fluid streams passing through purification fuses 50(a), 50(b), the level or concentration of a discontinuous phase liquid in a continuous phase fluid stream can be monitored without passing all of the fluid in these fluid streams through the purification fuses. For example, a portion of either or both of a contaminated or purified fluid stream can be diverted to produce a slip stream, which can pass through one or more purification fuses. The slip stream can have a lower mass or volumetric flow rate than a corresponding fluid stream (e.g., the fluid stream from which the slip stream originated), but can have about the same discontinuous phase liquid concentration as the corresponding fluid stream. The fluid in the slip stream can then pass through one or more smaller purification fuses, which can directly or indirectly indicate (e.g., by creating an increase in pressure drop across the fuse and/or a reduced flowrate downstream of the fuse) that the concentration of discontinuous phase liquid in the slip stream, and consequently the corresponding contaminated or purified fluid stream, is unacceptable. The use of smaller purification fuses in a slip stream to monitor the concentration of a discontinuous phase liquid in a fluid stream with a larger mass or volumetric flow rate than the slip stream can be advantageous. For example, smaller purification fuses are less expensive to produce and maintain than larger purification fuses. Also, by using one or more purification fuses in a slip stream to monitor the concentration of discontinuous phase liquid in a corresponding

fluid stream, the flow of the corresponding fluid stream will not be substantially inhibited by the presence of one or more purification fuses. This is because the concentration of discontinuous phase liquid in the corresponding fluid stream is monitored substantially indirectly, rather than directly.

Any one or more of the components of the embodiments can be combined with any one or more of the components of any of the other embodiments without departing from the scope and intent of the present invention. Also, although the present invention has been described in terms of exemplary embodiments and examples, it is not limited to those embodiments or examples. Alternative embodiments, examples, and modifications which would still be encompassed by the invention may be made by those skilled in the art, particularly in light of the foregoing teachings. Therefore, the following claims are intended to cover any alternative embodiments, examples, modifications, or equivalents which may be included within the spirit and scope of the invention as defined by the claims.

Claims

1. A purification element comprising:
a sorbing medium comprising a copolymer or derivative thereof;
the copolymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative, and an olefin comonomer.

2. The purification element of claim 1 wherein the copolymer is an olefin/alkylene carboxylate copolymer.

3. The purification element of any of claims 1-2 further comprising inorganic salts.

4. The purification element of any of claims 1-3 wherein the sorbing medium comprises a sorbing medium of the type available from Camelot Technologies, Inc., under the trade designation Fiberdri®.

5. The purification element of any of claims 1-4 wherein the sorbing medium comprises Fiberdri® sorbent.

6. The purification element of any of the preceding claims further comprising a drainage medium in fluid communication with the sorbing medium.

7. The purification element of any of the preceding claims wherein the purification element is generally cylindrical.

8. The purification element of any of the preceding claims further comprising a filter medium in fluid communication with the sorbing medium.

9. The purification element of any of the preceding claims wherein the purification element is pleated.

10. A purification element comprising:
a fibrous sorbing medium, the fibers of the sorbing medium comprising a polymer or derivative thereof, the polymer having recurring units of an unsaturated monomer having at least one pendant carboxylic acid or carboxylic acid derivative.

11. The purification element of claim 10 wherein the polymer is sodium poly(acrylic acid).

12. The purification element of claim 10 wherein the polymer is a copolymer.

13. The purification element of claim 12 wherein the copolymer is an olefin/alkylene carboxylate copolymer.

14. The purification element of any of claims 12-13 wherein the sorbing medium comprises Fiberdri®-type sorbent.

15. The purification element of any of claims 10-14 wherein the sorbing medium is pleated.

16. The purification element of any of the preceding claims further comprising a core, the sorbing medium being removably disposed around the core.

17. The purification element of any of the preceding claims further comprising a core, the sorbing medium being removably disposed within the cage.

18. A purification pack comprising:
a drainage layer adjacent to a sorbing medium.

19. The purification pack of claim 16 wherein the sorbing medium comprises Fiberdri®-type sorbent.

20. The purification pack of any of claims 16-17 wherein the pack further comprises a filter medium, and an additional drainage layer, the filter medium being downstream of the sorbing medium and the additional drainage layer being downstream of the filter medium.

21. The purification pack of any of claims 18-20 wherein at least one drainage layer includes an extruded mesh.

22. The purification pack of any of claims 18-20 wherein at least one drainage layer includes a bi-planar mesh or three-dimensional mesh.

23. A purification pack comprising:
an upstream drainage layer,
a sorbing medium,
a filter medium, and
a downstream drainage layer,
wherein the sorbing medium and filter medium are in fluid communication with each other, and are interposed between the upstream and downstream drainage layers.

24. The purification pack of claim 23 wherein the pack is co-corrugated.

25. The purification pack of any of claims 23-24 wherein the sorbing medium comprises Fiberdri®-type sorbent

26. The purification pack of any of claims 23-25 wherein at least one drainage layer includes an extruded mesh.

27. The purification pack of any of claims 23-26 wherein at least one drainage layer includes a bi-planar mesh or three-dimensional mesh.

26. A purification fuse comprising the filter element or purification pack of any of the preceding claims.

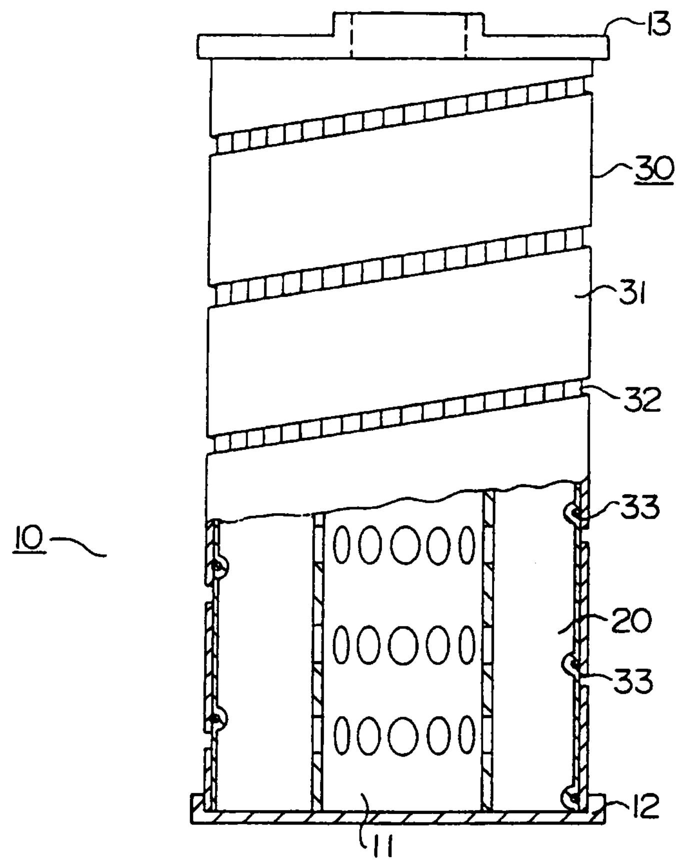

FIG. 1

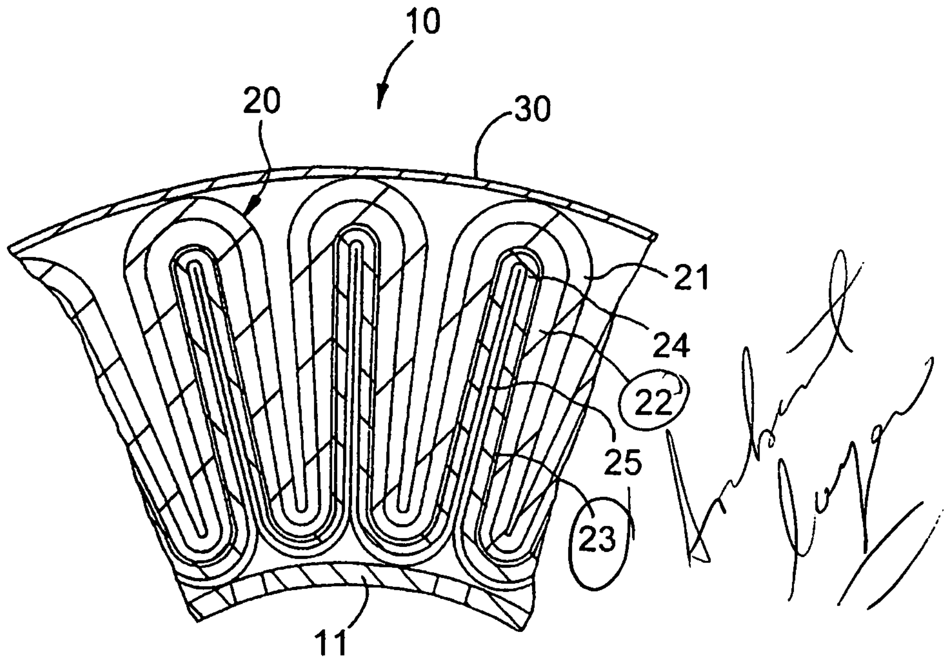

Fig. 2

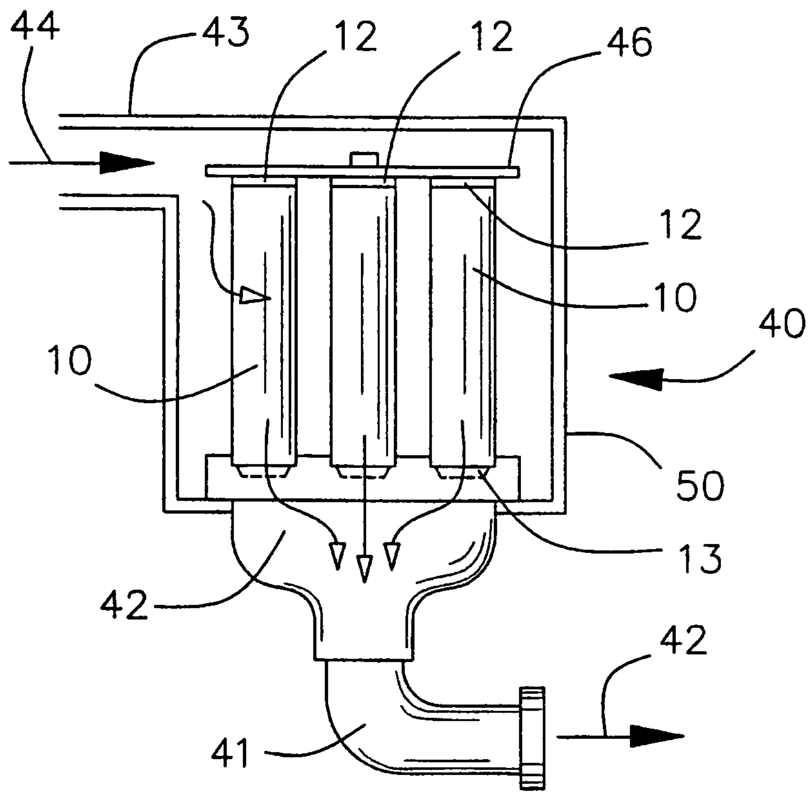

Fig. 3

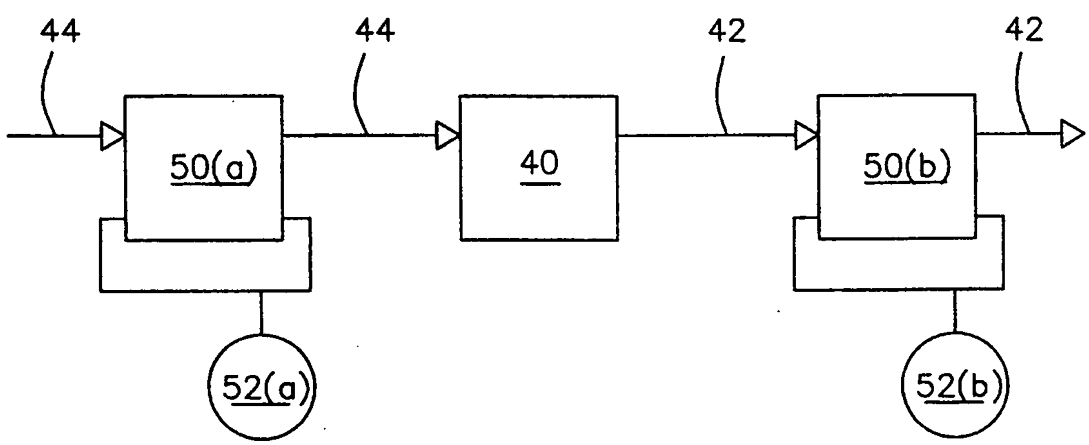

Fig. 4

INTERNATIONAL SEARCH REPORT

In .tional Application No
PCT/US 99/09572

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01J20/26 B01D29/11 B01D29/21 B01D39/18 B01D39/20
B01D39/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01J B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 15367 A (CAMELOT SUPERABSORBENTS LTD.) 1 May 1997 (1997-05-01) "Detailed description..." page 3 - page 8, paragraph FIRST	1,10
A	EP 0 272 074 A (ARCO CHEMICAL CO.) 22 June 1988 (1988-06-22) page 1 - page 5, line 49	1,10
A	US 5 252 207 A (MILLER ET AL.) 12 October 1993 (1993-10-12) cited in the application the whole document	23-27

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 July 1999	02/08/1999

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/09572

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9715367	A	01-05-1997	AU	7296396	A	15-05-1997
			CA	2242642	A	01-05-1997
			EP	0862488	A	09-09-1998
EP 272074	A	22-06-1988	US	4788237	A	29-11-1988
			CA	1331691	A	30-08-1994
			DE	3786537	A	19-08-1993
			DE	3786537	T	28-10-1993
			ES	2058130	T	01-11-1994
			HK	1007326	A	09-04-1999
			JP	2707089	B	28-01-1998
			JP	63222761	A	16-09-1988
US 5252207	A	12-10-1993	US	5084178	A	28-01-1992
			CA	2048086	A	31-01-1992
			DE	69122459	D	07-11-1996
			DE	69122459	T	06-02-1997
			EP	0470485	A	12-02-1992
			GB	2247189	A,B	26-02-1992
			GB	2274603	A,B	03-08-1994
			GB	2274604	A,B	03-08-1994
			JP	2753157	B	18-05-1998
			JP	4250804	A	07-09-1992
			JP	10113508	A	06-05-1998
			US	5552048	A	03-09-1996
			CA	1321552	A	24-08-1993
			DE	68914722	D	26-05-1994
			DE	68914722	T	04-08-1994
			EP	0347188	A	20-12-1989
			JP	1906402	C	24-02-1995
			JP	2043906	A	14-02-1990
			JP	6034885	B	11-05-1992